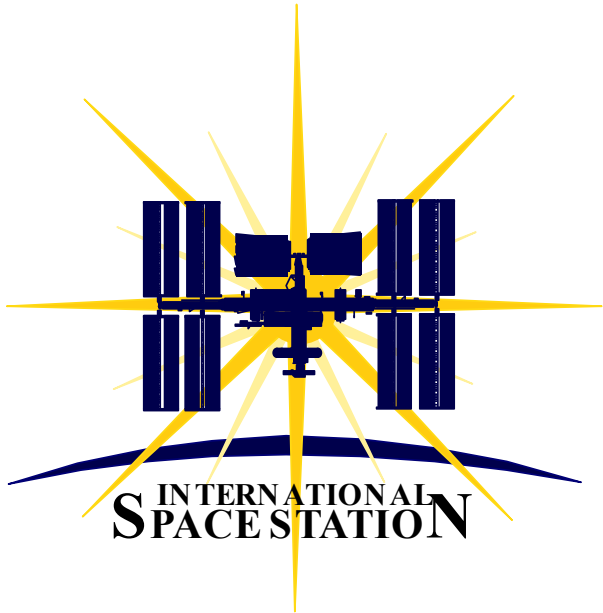

Robotic Operations Near the AMS Magnetic Field
MAGIK Action Item 1808

February 3, 2004

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Outline

- Purpose
- Background
- Assumptions
- MAGIK Development of 35 Gauss Envelope/Field
- MAGIK Development of 10 Gauss Envelope/Field
- Results
- Backup

Purpose

- **MAGIK Action Item (AI) 1808 documents whether it is kinematically feasible for all S1 and S3 robotically-compatible On-Orbit Replaceable Units (ORUs) to be removed and replaced using the Special Purpose Dexterous Manipulator (SPDM) and without penetrating a 10 Gauss magnetic field created by the Alpha Magnetic Spectrometer (AMS).**

Background

- MAGIK Action Item (AI) #1321 defined ORUs on S1 and S3 which require the SPDM to enter the 6 Gauss box, as defined in EMEP TIA # 0310.

- Results of AI #1321 were based on Boeing Huntington Beach EV&CS documentation which defined truss H fixtures used for SPDM stabilization for each specific ORU Remove & Replace (R&R).
  - 22 ORU R&R operations were identified which exposed the SPDM to the 6 Gauss box.

- MAGIK AI #1608 determined kinematic feasibility of each ORU R&R using alternate SPDM stabilization fixtures, and therefore removing the need for the SPDM to penetrate the 6 Gauss box. Additionally, AI #1608 used a modified 6 Gauss envelope/field created by MAGIK using the AMS magnetic field database.
  - 2 ORU R&R operations were identified which exposed the SPDM to the 6 Gauss field.

- MAGIK AI #1808 created a 10 Gauss field using the database. S1 and S3 ORU operations were again assessed.

Assumptions

- **As requested, this analysis only addresses kinematic feasibility by analyzing manipulator configurations during robotic tasks. Other areas not addressed in this document - lighting, combined EVA/EVR tasks, viewing, thermal and/or pressure effects on elements, and dynamics - could have a significant influence on manipulator configurations and overall feasibility.**

- **3D graphical models used in this analysis are a result of the MAGIK Team's "best efforts" to obtain/create accurate models reflecting actual volumetric dimensions of the various ISS elements. "Best efforts" include obtaining models directly from the ISS CAD Modeling Team, the hardware designers, or a 3rd party (a source other than the hardware designers), or creating models from hardware designer or customer provided drawings/information.**
  - The S3 Integrated Truss Segment (ITS) CAD model used in this analysis was created and verified by the MAGIK Team from the ISS 3D CAD Modeling Team's validated as-designed models of the S3 Truss.
  - The AMS CAD model used in this analysis was created by the MAGIK Team using a high fidelity model received from Ross Harold/LM in May, 2003.
  - The SPDM CAD model used in this analysis was based on models received from Layi Oshinowo/CSA in November, 1998. The link-lengths of the models were compared to Spar Drawing Number 51602-0004 Rev .-. There was no date on the drawing, and only sheet two of two was available. The individual models have not been validated, as there are no "truth models" yet available for the SPDM.
  - Pedigree information for other models may be obtained from the MAGIK Team upon request.

Assumptions - Continued

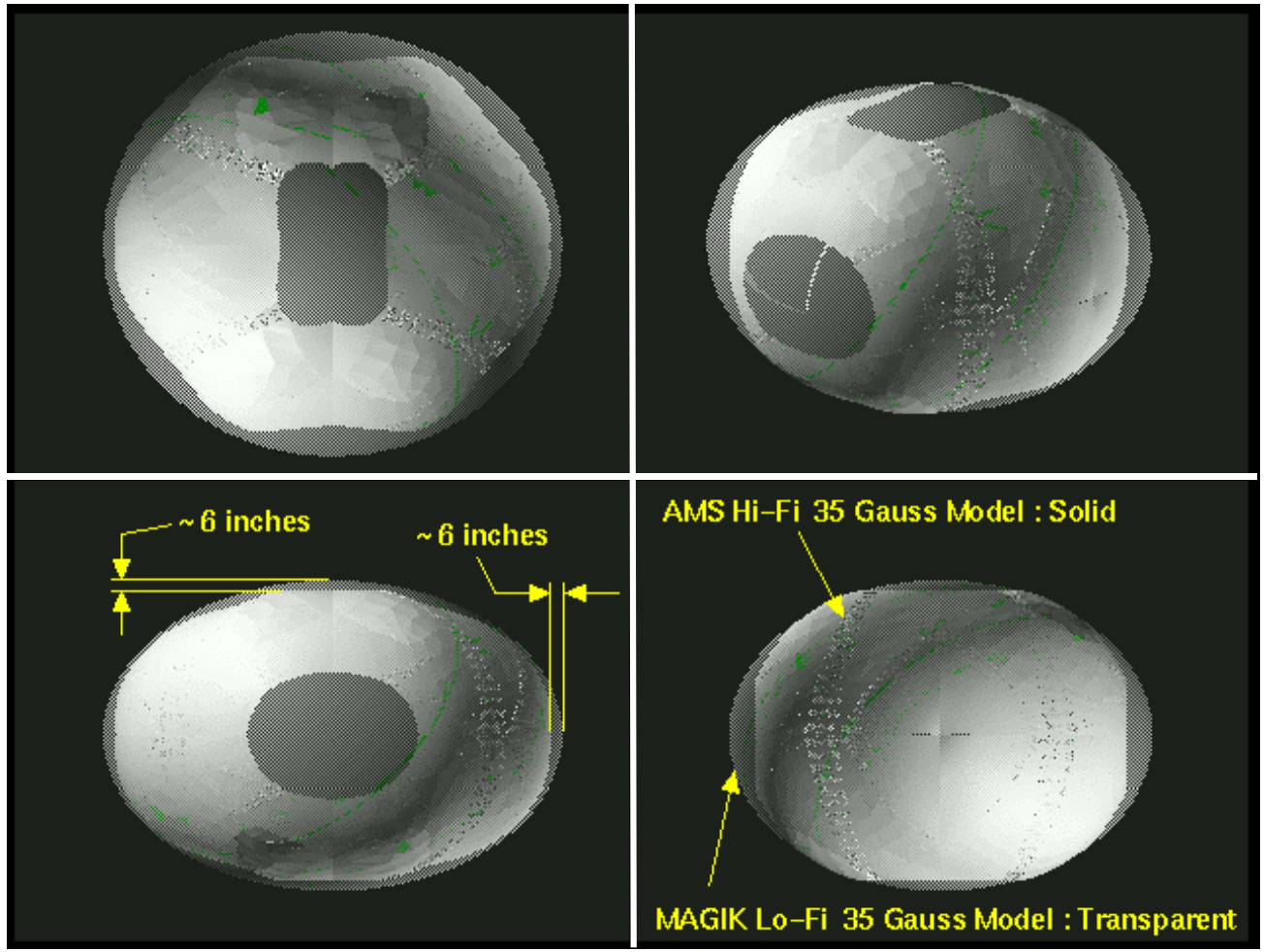
- The trajectories and specific robot joint angles used in this analysis are not necessarily the final configurations that will be used on-orbit. They represent a first-cut effort in the development of a feasible trajectory, which will later be refined as the operations are assessed by the Mission Operations Directorate (MOD).

- The center of the magnetic field is the center of the AMS model.

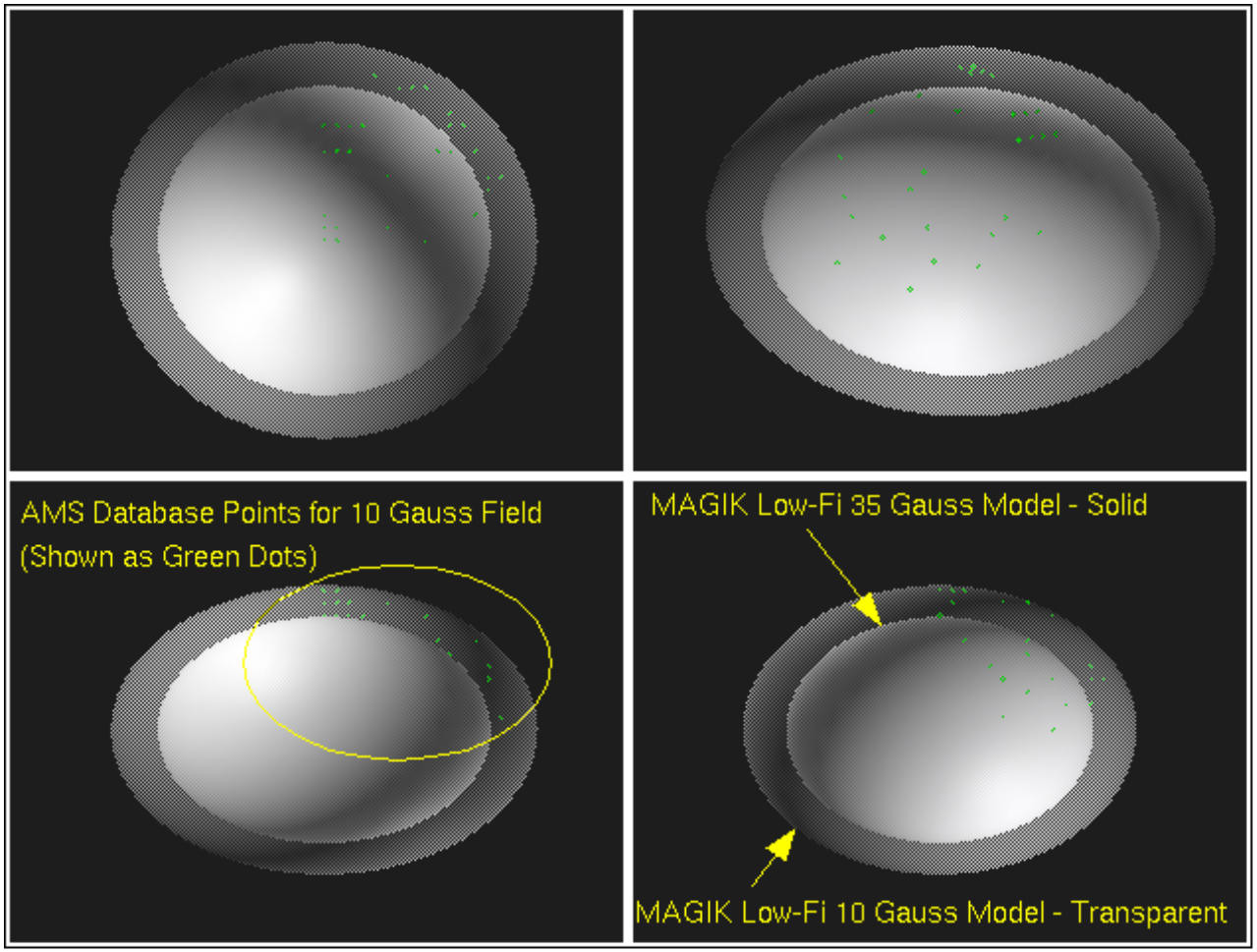
- The 6 and 10 Gauss MAGIK envelopes were created using a database of magnetic field readings obtained from Liz Cheshire/ER on 11/13/2001, who received it from Gene Cook/OZ, who received it from Stephen Voels/OZ, who received it from Trent Martin/LM.
  - Since the MAGIK Team does not know the database pedigree or how the data was obtained, whether experimentally or by analysis, and whether there is any error, uncertainty, or margin built into the data, the MAGIK Team cannot draw any definitive conclusions from this report.

MAGIK 35 Gauss Envelope/Skin Development

- High fidelity 3D CAD model of AMS 35 Gauss magnetic field received from LM.
- High Fidelity model was re-modeled by MAGIK in low fidelity.

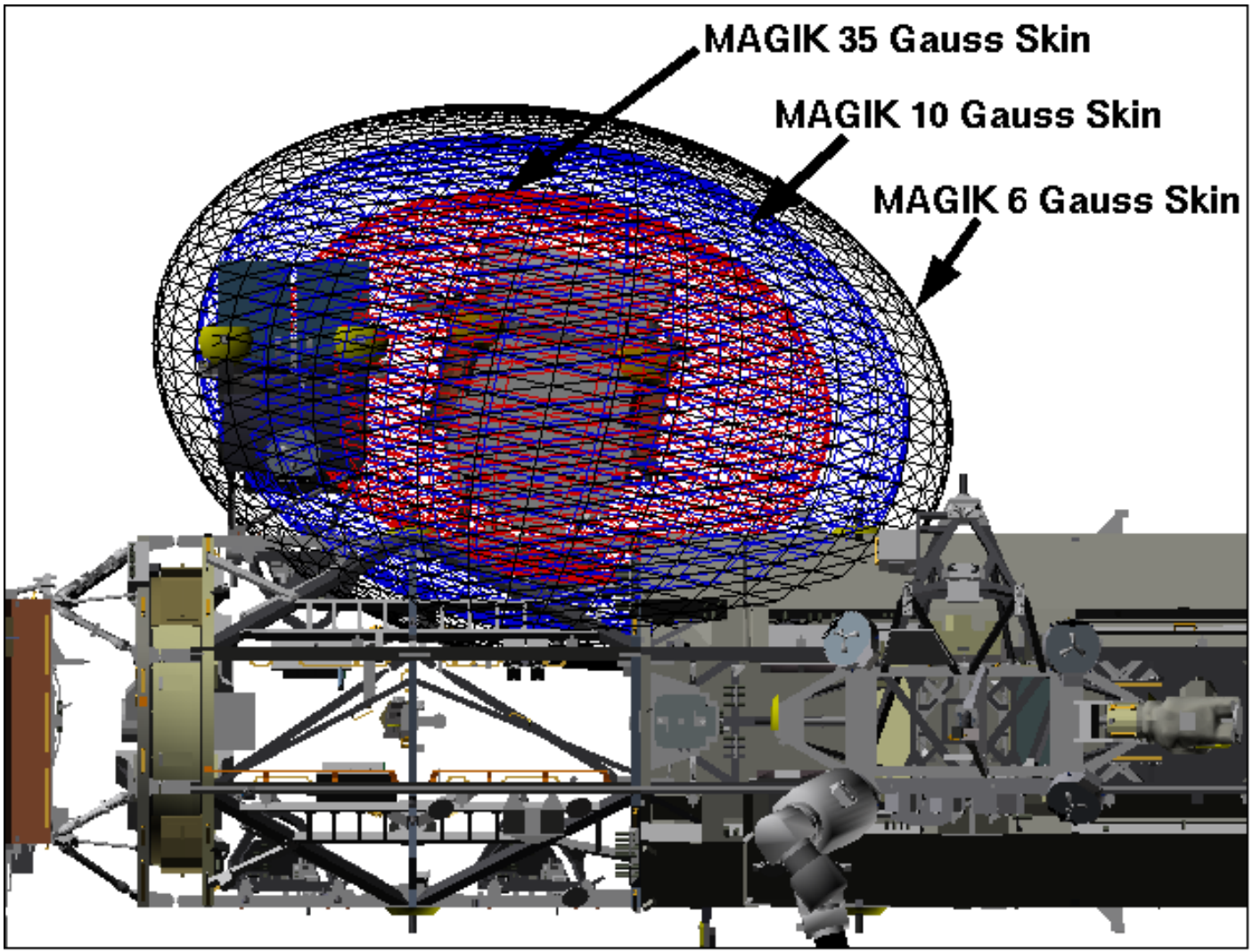


MAGIK 10 Gauss Envelope/Skin Development



- No 3D CAD model of the 10 Gauss field was provided to MAGIK, however, a database of field readings at many points around the AMS was provided.
- The database points for 10 Gauss magnetic field were plotted.
- The MAGIK low fidelity 35 Gauss envelope was then scaled until it just encompassed the 10 Gauss plotted points.
- This new envelope represents the MAGIK low fidelity 10 Gauss field.

MAGIK 10 Gauss Envelope/Skin Development

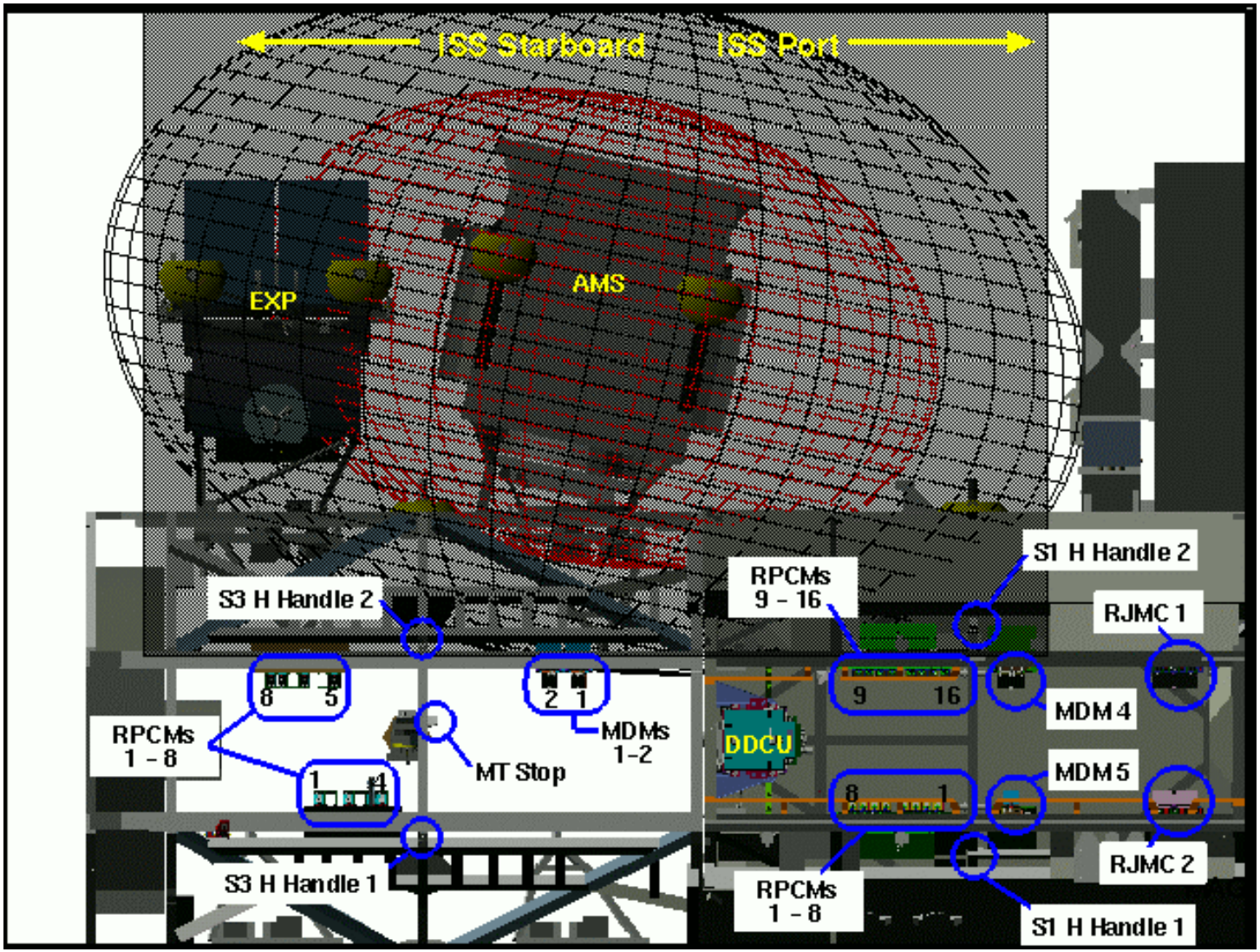


Results

- All S1 and S3 ORU operations assessed were found to be kinematically feasible while remaining outside of the MAGIK-created 10 Gauss envelope.
- The robot joint configurations identified by the MAGIK Team are flexible enough to provide a reasonable opportunity for change as the trajectories are further refined.

Backup Charts

Backup


ISS Starboard
ISS Port
EXP
AMS
S3 H Handle 2
RPCMs
9 - 16
S1 H Handle 2
RJMC 1
MDM 4
MDM 5
RJMC 2
S1 H Handle 1
RPCMs
1 - 8
MDMs
1-2
MT Stop
DDCU
S3 H Handle 1
RPCMs
1 - 8

Summary of Analyses Performed

- **AI #1321 defined the following ORUs would necessitate the SPDM entering the 6 Gauss box:**
  - **S1:** RPCMs 1-8, DDCU, RJMC 2, & MDM 5
  - **S3:** RPCMs 1-8, MDMs 1 & 2, MT Stop

- **AI #1608 defined the following ORUs necessitate SPDM penetration of the 6 Gauss MAGIK envelope:**
  - **S1:** None
  - **S3:** RPCMs 3 & 4
    - (*Note that the Stabilizing Arm violates the envelope, due to use of H Handle #2 – H Handle #1 could not be used to stabilize, as it is less than 36 inches from the ORU Task Arm H Handle)

- **AI #1808 defined determined all S1 and S3 ORUs are accessible without penetrating the 10 Gauss MAGIK envelope.**

SPDM Access to S3 RPCM 3